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The efficacy of prebiotic supplementation in mitigating heat stress and improving the survival of antibiotic-free broilers' production in hot climates

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Abstract

Background Bangladesh is a hot tropical country, and various antibiotics have been included in broiler feed for many years to manage, prevent, and treat illnesses and improve production performance, like many other developing countries. This study mainly evaluates the efficacy of prebiotic supplementation in mitigating heat stress and improving the survival of antibiotic-free broiler production in hot climates.

Materials and methods A cocktail of banana peel, papaya peel, and watermelon rind was used as a prebiotic. A total of 350 one-day-old chicks (Ross-308) were allotted into five treatment groups each with 7 replicates: T_1 (prebiotics, 15 ml/L), T_2 (commercial probiotics Lactolase P, 1 g/L), T_3 (synbiotics, 7.5 ml/L prebiotics + 0.5 g/L probiotics), T_4 (freshwater), and T_5 (antibiotics, 1 g/L). Besides other treatments, the aqueous extracts of banana peels, papaya peels, and watermelon rinds were prepared as prebiotics, and these were provided to the experimental birds through drinking water from 5 to 32 days of age.

Results The findings revealed nonsignificant ($P > 0.05$) variations in water intake, feed intake, feed conversion ratio (FCR), dressing weight, dressing percentage, heart and gizzard weights, and thigh meat yield. Significant ($p < 0.05$) differences were observed in body weight, body weight gain, and breast meat yield. It was observed that birds consumed five times more water than feed when the environmental temperature was above 38 °C. Significant ($p < 0.05$) differences in the survival rates of birds were observed among treatment groups. The highest rate of survival was obtained in T_1 (100%), followed by T_2 (93.3%), and T_3 (90%), and the lowest percentage was recorded in T_4 (66.6%) and T_5 (73.3%).

Conclusion Prepared prebiotics could mitigate heat stress, promote growth rate under hot climates, and be used as substitutes for antibiotics to safely produce broilers in hot climates.

Keywords Broilers, Prebiotics, Production performance, Survivability, Synbiotics

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Introduction

The key factors adversely affecting the viability of poultry production in the tropics are weather fluctuations and the use of antibiotics [1]. The impact of climatic volatility has become a critical problem for poultry farming globally and in Bangladesh. One of the most important environmental factors affecting the performance of chickens is heat stress, which influences feed intake, growth rate, body weight gain, meat quality, egg quality, egg production, semen quality, and fertility. Birds experience heat stress when they fail to balance the heat produced and lose it [2]. Heat stress is a problem that has consistently been linked to poor broiler performance [3, 4]. Heat stress affects the physiological, behavioral, and immune systems of broilers [5]. To manage, prevent, and treat illnesses as well as improve performance and feed efficiency, various antibiotics have been included in broiler feed [6]. Antibiotics are chemical agents that kill or inhibit the growth of microorganisms. They are used to treat diseases by destroying pathogenic microorganisms or inhibiting their growth at a concentration low enough to avoid causing damage to the host [7].

As a result of the increase in antibiotic-resistant microbes, commonly known as 'antimicrobial resistance,' the European Commission (EC) decided to gradually ban antibiotics as growth promoters in animal feeds, ultimately resulting in a complete ban as of January 1, 2006 [8]. Antibiotics have been crucial in conventional medicine, but resistance is a growing threat. Overuse and inappropriate prescriptions contribute to antibiotic resistance; therefore, antibiotic use is not currently recommended in many countries [9]. Unfortunately, in developing countries, such as Bangladesh, sales and distribution of antibiotics are allowed without a prescription, which is often associated with shorter/incomplete treatment courses, incorrect selection of antibiotics, and inappropriate doses [10]. Informal prescribers (IPs) serve as middlemen between the sale and administration of antibiotics and are involved in the poultry and larger animal industries. Most of them do not visit a veterinarian before selling or prescribing antibiotics [11]. To eliminate these malpractices, probiotics and prebiotics are used as alternatives to antibiotics. A probiotic is a live microbial feed supplement that quickly establishes in the gut to suppress the colonization and growth of harmful bacteria and improve its intestinal microbial balance [12]. Prebiotics are compounds in food that induce the growth or activity of beneficial microorganisms such as bacteria and fungi. Gibson and Roberfroid [13] were the first to discuss prebiotics. They defined prebiotics as "a non-digestible food element that beneficially impacts the host by selectively encouraging the growth and/or activity of one or a restricted number of bacteria in the colon, enhancing host health. "This definition was later updated by Gibson et al. [14], who redefined a prebiotic as 'a selectively fermented ingredient that allows specific changes, both in the composition and/or activity in the gastrointestinal (GIT) microflora that confers benefits upon host wellbeing and health.' Studies conducted over the last ten years indicate that prebiotics may improve the gut health, immune system, stress tolerance, and gut microbiota composition of heat-stressed broilers, promoting growth and overall wellbeing [15–18]. Furthermore, the term synbiotics refers to a combination of probiotics and prebiotics. Synbiotics combine the beneficial effects of both probiotics and prebiotics, improving the survival of live microbial dietary supplements in the gastrointestinal tract [19, 20].

Prebiotics and probiotics are becoming popular in poultry production to mitigate environmental stressors and diseases due to global warming and therapeutic threats. Prebiotics generally change gut microbes by increasing their population, improving digestion, lowering harmful bacteria, increasing mineral and vitamin absorption, maintaining ideal intestinal pH, and maximizing nutrient absorption [10, 11, 21]. By enhancing the intestinal microbiota, gut architecture, oxidative status, physiological stress response, and ultimately, growth performance of broiler chickens, prebiotics may reduce the harmful effects of heat stress [22].

Banana (*Musa acuminata*) peels are edible and rich in vital nutrients, including potassium, polyphenol carotenoids, antioxidants, dietary fiber, polyunsaturated fats, and essential amino acids [23]. Magnesium, potassium, and vitamins B6 and B12 are significant amounts in banana peels. Additionally, banana peels contain fiber and protein, which improving immunity and digestion. Papaya peel (*Carica papaya*) is a good protein, fiber, minerals, and β-carotene source. Because papaya peel is rich in antioxidants, it can release free radicals. It possesses significant levels of natural antioxidants, and consuming papaya peel extract can help to successfully kill pathogenic bacteria such as *E. coli*, *Salmonella*, *and Staphylococcus,* thus enhancing gut health and reducing the risk of disease [24]. Watermelon (*Citrullus lanatus*) rind contains low calories but high concentrations of vitamins C, A, and B6, potassium, zinc, and several antioxidants. It is also nutrient-dense and contains chlorophyll, citrulline, lycopene, amino acid flavonoids, and phenolic compounds.

Notably, nowadays, researchers have focused on interventions that mitigate the adverse effects of heat stress. Due to increased public awareness and the wealth of information, heat stress and food safety issues have taken particular importance [25]. Heat stress has become an increasingly severe problem because of global warming and issues with food security. The effects of heat stress on chicken productivity significantly impact the broiler industry. Therefore, a range of tactics have been used to reduce heat stress. Owing to the advantages that prebiotics provide for the wellbeing and performance of heat-stressed broilers, there is a growing interest in their use.

Bananas, papaya, and watermelon are abundantly produced in all areas of Bangladesh, and their peels are thrown away here and there. These fruit byproducts were selected because they are rich in vital nutrients that minimize heat stress. Considering this fact, reusing these waste resources was our prime concern. Therefore, in this study, a cocktail of banana peel, papaya peel, and watermelon rind was used as a prebiotic, besides commercial probiotic, and symbiotic to mitigate heat stress, enhance production performance, and increase survival of birds at high ambient temperature (HT).

Materials and methods

Experimental design, duration, and preparation of the prebiotic extract

350 one-day-old Ross 308 commercial mixed-sex broiler chicks were subjected to a 32-day (marketable age) experiment. Upon arrival, the chick's body weight was measured individually, and the average weight of the chicks was 46 g. The chicks were then allotted into five treatment groups each with seven replicates each containing 10 chicks: T_1 (prebiotics, 15 ml/L), T_2 (commercial probiotics Lactolase P, 1 g/L), T_3 (synbiotics, 7.5 ml/L prebiotics + 0.5 g/L probiotics), T_4 (freshwater), and T_5 (antibiotics, 1 g/L) (Fig. 1a).

Banana peels, papaya peels, and watermelon rinds were collected from local markets and restaurants. The collected fruit byproducts were washed with tap water, and the dark borders and section retaining debris of the collected peels were removed. Washed peels and rinds were cut with a knife for processing and weighed (50 g each) using an electric balance. Then, it was ground and mixed with distilled water

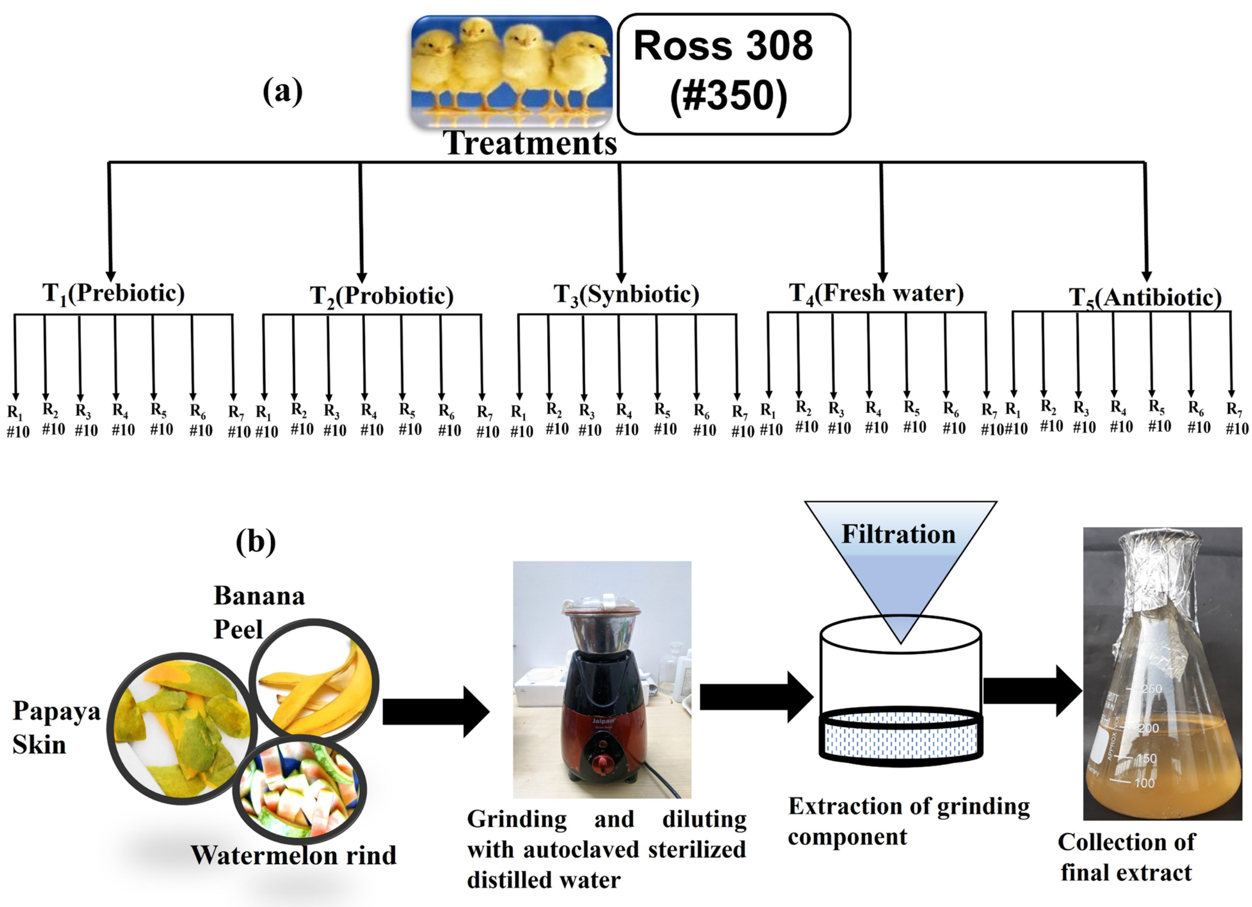

Fig. 1 Experimental design (**a**) and schematic representation of the preparation of prebiotic extract (**b**)

(1000 ml) in a Jaipan blender (Fig. 1b). To obtain the fine extract, straining was performed using a fine sieve at least three times before moving on filter paper and then filtered via Whatman filter paper, and the fresh extract was collected in a clean jar. The extracted solution was stored in a refrigerator and uniformly dissolved in drinking water daily.

Digestion and calibration of watermelon rinds and papaya and banana peels for chemical analysis

The watermelon rind, papaya peel, and banana peel samples were digested using the wet ash digestion method [26]. The concentrations of these minerals were determined by atomic absorption spectroscopy. The samples were dried at 70 °C using an oven for 24 h. The dried samples were then ground into a powder using a mortar and pestle to prepare them for digestion. A mixture of 12.0 mL nitric acid and 4.0 mL perchloric acid was used to mineralize 2.0 g of the powdered samples under reflux in a 100 mL round bottom flask with a ground glass joint. It took 5 h of digestion to produce a clear solution. The solution was then transferred to a 100-mL volumetric flask and filtered using Whatman filter paper, and the volume was marked. Finally, the concentrations of Ca, K, Zn, and Na were determined using an atomic absorption spectrophotometer (Shimadzu, Japan, AA-6800) equipped with a flame and graphite furnace at the Central Science Laboratory of Rajshahi University. However, detailed instrumental and calibration measurements were performed according to the methods of Mannan et al. [26].

Feeding, watering, and management of birds

Chick starter was given to the day-old chicks by spreading it on the newspaper for the first 3 days. After that, feed was provided ad libitum in the linear feeders for up to one week of the experimental period. A weighed quantity of feed was supplied to each feeder, which was then refilled whenever it emptied. After one week, more than two-thirds of the feeders were not filled to minimize the waste of feed. During the first 14 days of the experiment, the chicks were fed a broiler starter ration (CP 22%, ME 3000 kCal/kg), and from the 14th day up to the 32nd day, the grower ration (CP 21%, ME 3100 kCal/kg) was fed to the broiler chicken, which was purchased from the local market. The aqueous extracts of banana peels, papaya peels, and watermelon rinds were prepared as prebiotic, commercial probiotics (Lactolase P), and their combination was provided to the experimental birds through drinking water at different doses from 5 to 32 days of age. The treatments used were 15 mL/L prebiotics (T_1), 1 g/L probiotics (T_2), 7.5 mL/L prebiotics + 0.5 g/L probiotics (synbiotics, T_3), freshwater (T_4), and 1 g/L antibiotics (T_5). Notably, an equal proportion of banana and papaya peels and watermelon rinds were used as prebiotics. The birds were assigned to various biotic treatments and only the ambient temperature regime was considered as different levels of temperature. Generally, during the summer season, the ambient temperature became very high in the study area and the recorded temperature ranges from 34 °C to 42 °C (Fig. 2). Therefore, there were no imposed or designed temperature regimes where birds were assigned during the experimental period. The ambient temperature of the shed during the experiment was recorded using a digital thermometer daily from 12

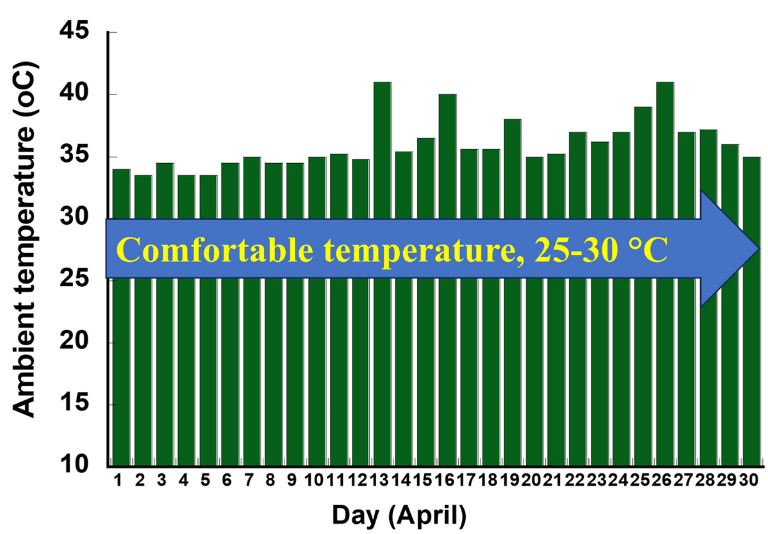

Fig. 2 The recorded ambient temperature (°C) during the experimental period

p.m. to 4 p.m. The ambient temperatures below 20 °C, 25 °C to 30 °C, and 31 °C to 50 °C were considered too low, comfortable, and dangerous, respectively, for broilers [27]. The temperature recorded during the experiment is presented in Fig. 2. Because of our interest in the effects of prebiotics and probiotics on the survival and production performance of antibiotic-free broilers at HT (over 37 °C), vitamin C and other electrolytes were not supplied with water. All experimental chicks were vaccinated against Marek's disease on the first day of life at the hatchery, and the subsequent standard vaccination schedule was followed during the experimental period.

Parameters studied

The data were collected until the end of the experimental period (32 days). The daily feed and water intake and the production performance in terms of body weight and body weight gain of the birds were recorded. The feed conversion ratio (FCR) was calculated as the proportion of cumulative feed intake to final body weight gain. Carcass characteristics were studied during the experimental period by randomly selecting three birds per replicate for sacrifice, and the dressed weight, dressing percentage, thigh meat yield, breast meat yield, and giblet (heart, liver, gizzard) weight were recorded. The pH of water supplemented with prebiotics (T_1), probiotics (T_2), synbiotics (T_3), fresh water (T_4), and antibiotics (T_5) was measured using a digital pH meter. The influences of pH on water and feed intake throughout the study period were measured in various groups. In addition, HT was measured and analyzed until the end of the experiment. Mortality was recorded during the experimental period. The survival of the birds from each treatment was recorded until the end of the experiment.

Statistical analysis

The data were analyzed using SPSS software analysis of variance (ANOVA) (See supplementary material) and a completely randomized design (CRD). Means were compared to determine the significance of differences by the LSD test. Statistical significance was set at 1% level ($P \leq 0.01$) and 5% level ($P \leq 0.05$).

Results

Chemical composition of watermelon rinds, and papaya and banana peels

In this study, we determined the concentrations of several vital minerals, i.e., Ca, K, Zn, and Na. The concentrations (mg/100 g) of Ca, K, Zn, and Na obtained from watermelon rinds, papaya peels, and banana peels are shown in Table 1.

Table 1 Mineral compositions of watermelon rind, banana peels, and papaya peels

Item	Minerals (mg/100 g)			
	Ca	K	Zn	Na
Watermelon rinds	32. 50 ± 1.25	13.7 ± 0.25	2.9 ± 0.05	15.16 ± 0.52
Banana peels	29.12 ± 0.20	76.11 ± 3.20	-	28.33 ± 2.15
Papaya peels	38.60 ± 1.50	550.13 ± 2.05	2.70 ± 0.25	49.01 ± 3.01

Here, *Ca* Calcium, *K* Potassium, *Zn* Zinc and *Na* Sodium

Effects of treatments on feed and water intake, pH of drinking water, and production performance

The average cumulative feed intake (kg) and water intake (L) during the experimental period are presented in Table 2. The feed intake was the highest (2.68 kg) and the lowest (2.29 kg) for T_1 and T_5, respectively. On the other hand, the highest (8.47 L) and lowest (7.56 L) amounts of water were consumed by T_4 and T_5, respectively. The recorded live weight was the highest (1.88 kg) and the lowest (1.54 kg) for T_1 and T_5, respectively. Furthermore, the highest live weight gain of the experimental birds at 32 days of age under T_1 was 1.76 kg, whereas, the lowest live weight gain was recorded for T_5 (1.42 kg). The best FCR was obtained in the T_1 group of broilers after supplementation with prebiotics through drinking water (1.41) whereas the worst FCR was noticed in T_5 (1.58) (Table 2).

The pH of the drinking water after mixing the supplements was measured, and the obtained pH values for T_1, T_2, T_3, T_4, and T_5 were 6.94, 6.86, 6.73, 7.30, and 7.20, respectively (Table 2).

Effects of treatments on carcass characteristics

The mean values for dressing weight and dressing percentage of the experimental broilers under various treatments are displayed in Table 3. The highest dressing weight and dressing percentage were recorded for T_1 (1.70 kg/b) and T_2 (78.71%), respectively. Similarly, the highest breast and thigh meat weights were obtained for $T_{1,}$ 486.67 and 223.33 g/b, respectively (Table 3). Furthermore, the observed giblet (heart, liver, and gizzard) weights of the experimental broilers after supplementation with prebiotics, probiotics, or their combination are presented in Table 3. The highest heart weight was 9.67 g/b in T_1, whereas the highest liver and gizzard weight were 49.00 and 52.67 g/b, respectively, in T_2.

Effect of heat stress on feed intake, water intake, and survival rate of birds

At HT, birds consume more water and reduce their feed intake [28]. The effects of heat stress on water and feed intake under various treatments are presented in Fig. 3.

Table 2 Effects of treatments on feed intake, water intake, and production performance

Parameter	Treatment (mean ± SD)					P value
	T_1	T_2	T_3	T_4	T_5	
Feed intake (Kg/b)	2.68 ± 0.12	2.63 ± 0.20	2.630 ± 0.19	2.63 ± 0.15	2.29 ± 0.20	0.12
Water intake (L/b)	7.98 ± 0.17	7.69 ± 0.24	7.93 ± 0.24	8.47 ± 0.51	7.55 ± 0.50	0.08
Water pH	6.94	6.86	6.73	7.30	7.20	-
Body weight (Kg/b)	$1.88^a \pm 0.04$	$1.81^b \pm 0.23$	$1.87^a \pm 0.27$	$1.78^c \pm 0.06$	$1.54^d \pm 0.06$	< .0001**
Body weight gain (Kg/b)	$1.76^a \pm 0.04$	$1.69^b \pm 0.23$	$1.75^a \pm 0.26$	$1.67^c \pm 0.06$	$1.42^d \pm 0.06$	< .0001**
FCR	1.41 ± 0.07	1.43 ± 0.20	1.42 ± 0.14	1.49 ± 0.06	1.58 ± 0.17	0.11

** 1% level ($P \leq 0.01$)

a, b,c,d Means in the same row with different letters show significant differences

Table 3 Effects of prebiotics and probiotics on carcass characteristics

Parameter	Treatment (mean ± SD)					P value
	T_1	T_2	T_3	T_4	T_5	
Dressing weight (kg/b)	1.70 ± 0.09	1.66 ± 0.34	1.65 ± 0.26	1.46 ± 0.10	1.39 ± 0.07	0.32
Dressing %	77.63 ± 0.59	78.71 ± 8.52	73.84 ± 5.19	71.27 ± 3.90	70.48 ± 1.67	0.24
Breast meat (g)	$486.67^a \pm 12.58$	$415.00^{ab} \pm 83.22$	$396.67^b \pm 47.25$	$352.67^b \pm 16.62$	$361^b \pm 56.15$	0.05*
Thigh meat (g)	223.33 ± 20.21	206 ± 46.13	195 ± 43.59	156.33 ± 45.17	154.33 ± 18.34	0.11
Heart wt. (g)	9.67 ± 0.58	7.67 ± 1.52	7.33 ± 2.51	9.00 ± 1.00	7.00 ± 1.00	0.20
Liver wt. (g)	$47.33^a \pm 0.58$	$49.00^{ac} \pm 7.94$	$45.33^{bc} \pm 6.51$	$40.67^{abc} \pm 3.06$	$37.33^{bc} \pm 3.21$	0.02*
Gizzard wt. (g)	51.33 ± 4.93	52.67 ± 7.51	46.00 ± 6.00	51.00 ± 2.65	43.33 ± 6.11	0.27

* 5% level ($P \leq 0.05$)

a, b,cMeans in the same row with different letters show significant differences

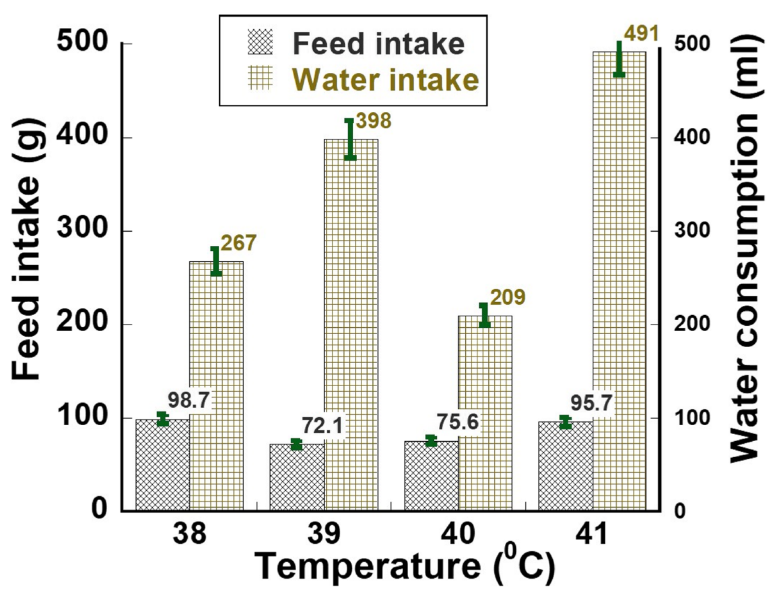

Fig. 3 Effect of heat stress on water and feed intake under various treatments

The feed (g) and water (ml) intakes were respectively 98.7 and 277 at 38 °C, 72.1 and 398 at 39 °C, 75.6 and 209 at 40 °C; and 95.7 and 491 at 41 °C. The mortality of broilers increased with increasing temperature. The number of birds died during the experimental period were 2, 3, 7, and 11 at 38 °C, 39 °C, 40 °C, and 41 °C, respectively. Moreover, 1, 7, 2, 3, and 10 birds died on days 16, 19, 22, 28, and 29, respectively, at 41 °C, 40 °C, 38 °C, 39 °C, and 41 °C (Fig. 4a). The highest mortality was recorded on days with the highest ambient temperature. The recorded survival rates of the experimental broilers were 100, 93.33, 90, 66.67, and 73.33% in T_1, T_2, T_3, T_4, and T_5, respectively (Fig. 4b).

Discussion

The results revealed an insignificant difference in feed intake among the treatments. Prebiotics, synbiotics, and probiotics have all been thoroughly studied to replace antibiotic growth promoters (AGPs) in broiler diets and to mitigate the adverse effects of increasing ambient temperature, given the current global initiative to ban or reduce the use of AGPs in broiler production [26, 29]. It has been reported that feed intake is improved by

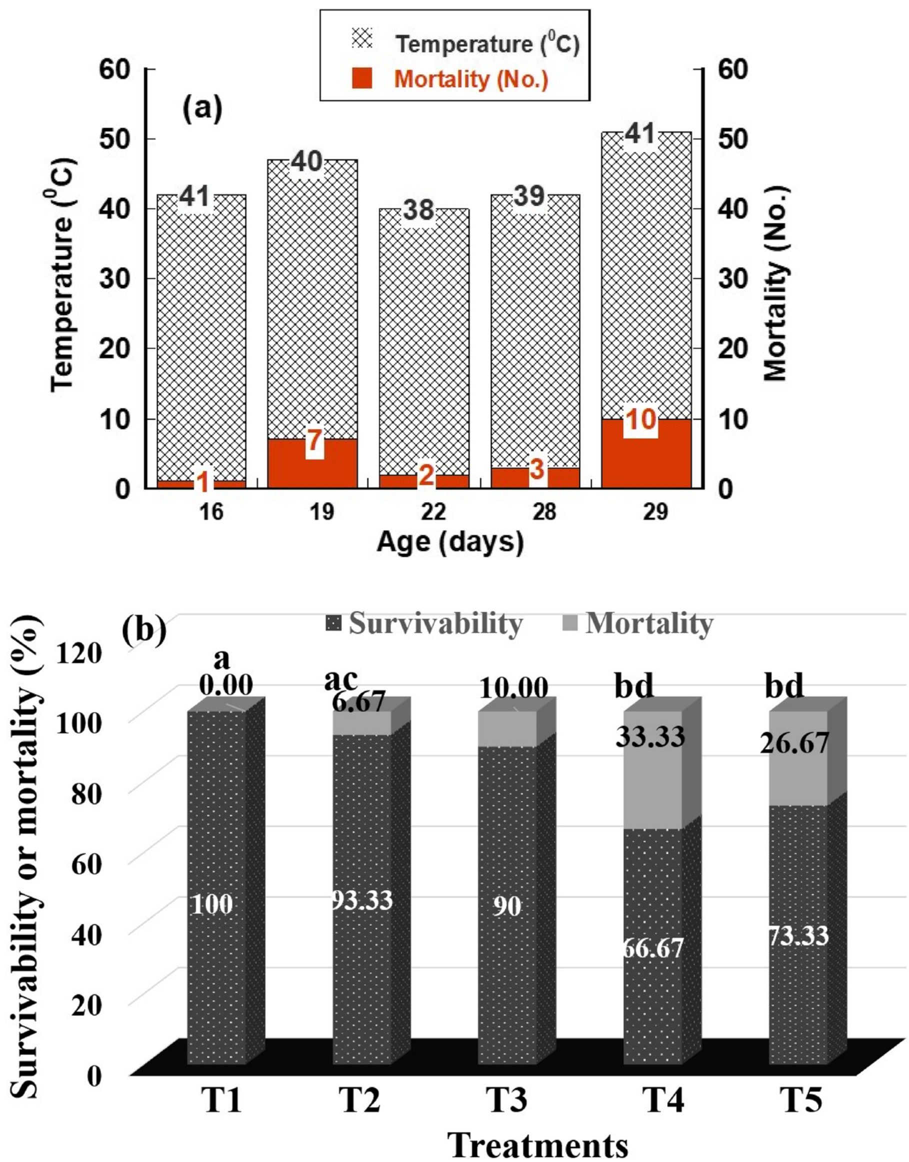

Fig. 4 Relationships among high ambient temperature, mortality, and age of birds (**a**) and the effect of high ambient temperature on the survival of birds in various treatment groups (**b**)

supplementation with probiotics and prebiotics. Supplementation with probiotics decreased gastric emptying time, which led to increased feed intake [4]. However, this earlier research has supported the conclusions of the present study. In contrast, some scientists observed that probiotic supplementation did not affect feed intake [15]. In contrast to these findings, some researchers observed that feed intake was decreased by supplementation with prebiotics and probiotics [30]. Olnood et al. [31] also reported reduced feed intake by adding synbiotics (probiotic + prebiotic) to the broiler diet. Furthermore, it was reported that the interaction of prebiotics and probiotics did not affect feed intake during all phases [32]. However, in this study, it was found that the supplementation of prebiotics improved feed intake because of the greater metabolic activity in the intestine.

An insignificant difference in water intake among the treatments was obtained. Age, ambient temperature, relative humidity, specific dietary components, drinker type, and growth rate all affect the amount of water a bird consumes [33]. According to Orakpoghenor et al. [34], broiler chicks up to seven days old have a thermoneutral temperature range between 28 and 35 °C. Temperatures greater than these may cause hyperthermia and dehydration, reduced feed intake, and delayed growth [32]. Acute heat stress-exposed broilers reportedly exhibit increased water consumption [35]. Heat stress causes significant water loss through the respiratory system and increases water intake. It is assumed that the non-supplemented control group (T_4) consumed the maximum amount of water due to the normality of drinking water in HT. The antibiotic-supplemented group (T_5) consumed the lowest amount of water because antibiotic supplementation changed the color and pH of the drinking water.

The treatment groups had significant differences in body weight and body weight gain. Soomro et al. [35] reported that supplementation with probiotics significantly impacts carcass production, live weight gain, the immune system, and noticeable cut-up meat sections. In broilers, probiotics (20 g/kg of ration) had a positive impact on the growth rate due to good intestinal health, leading to better nutrient digestion and absorption with enhanced nutrient availability [36]. Sohail et al. [15] reported that synbiotics did not affect weight gain. However, the individual effects of probiotics and prebiotics were similar to the findings of other scientists who reported increased weight gain with increased levels of prebiotics. The improvement in weight gain might be associated with the ability of probiotics to secrete enzymes such as amylase, protease, and lipase, which might improve the digestion rate of feed nutrients and thereby increase the digestibility of starch, fat, and protein. Therefore, increased nutrient availability may improve live weight gain in broilers [36]. In contrast to these findings, Nyamagonda et al. [37] reported that weight gain decreased with the addition of synbiotics. In addition, weight gain decreased during the first 21 days of the experiment with the addition of probiotics [38]. The feed intake of the antibiotic-supplemented group (T_5) was the lowest among the treatments; therefore, body weight did not increase compared to other groups. Antibiotics promoted growth, and in the HT treatment, the addition of antibiotics to the broilers' diet caused a decrease in body weight due to heat stress. It was found that prebiotics could increase the growth performance of broilers by reducing the harmful effects of heat stress on the intestinal microbiota, gut architecture, oxidative state, and physiological stress response.

The concentrations (mg/100 g) of Ca, K, Zn, and Na in watermelon rinds were 29.15, 1.37, 1.29, and 12.65, respectively [39]. Similarly, Anhwange et al. [40] investigated the concentrations (mg/100 g) of Ca, K, Zn, and Na in banana peels and reported 19.20, 78.10, 00, and 24.30, respectively. Furthermore, the concentrations (mg/100 g) of Ca, K, Zn, and Na in papaya peels were 18.61, 516.33, 1.29, and 9.61, respectively [41]. However, it is noteworthy that the concentrations (mg/100 g) of Ca, K, Zn, and Na in watermelon rinds, banana peels, and papaya peels were higher in the present study compared to previous studies. The higher concentrations of Ca, K, Zn, and Na are assumed to be due to the studied fruits' geographical location, soil fertility, and variety. Therefore, prebiotic-supplemented broilers' enhanced performance and survival may be due to Ca, K, Zn, and Na balance under heat stress conditions.

The current findings revealed that an insignificant difference between the FCR of the treatment and control groups during the experimental period. The better FCR was observed in T_1 (1.41), followed by T_3 (1.42), T_2 (1.43), and T_5 (1.49). On the other hand, the worst FCR (1.58) was observed in T_5 (antibiotics-supplemented group). Likewise, probiotics in a broiler diet did not affect FCR [5]. This can be explained by the fact that a more balanced biota population in the gut due to substrate availability could lead to greater efficiency in digestibility and utilization of feed, resulting in enhanced growth and improved FCR [36]. It was also reported that FCR was decreased by adding prebiotics to the broiler diet compared to the control group. In contrast, the addition of prebiotics did not have the same effect as probiotics [42]. Similarly, Rokade et al. [43] reported that dietary supplementation with 0.30% mannan oligosaccharides significantly reduced the FCR (1.84 vs. 1.91) of broilers compared with that of their control counterparts from 14 to 42 days of age in a hot dry summer environment. In the same study, supplementation with 0.50% mannan oligosaccharides significantly increased body weight gain and decreased FCR from 14 to 42 days of age (1437.2 vs. 1281.7 g and 1.81 vs. 1.91, respectively). Cheng et al. [44] reported significantly greater average daily gain (56.3 vs. 51.2 g), average daily feed intake (96.4 vs. 89.7 g), and a lower feed/gain ratio (1.71 vs. 1.75) in broilers fed 0.025% mannan-oligosaccharides from 1 to 42 days of age than in those fed a control diet under heat stress conditions.

The effects of prebiotics, probiotics, and synbiotics on the dressing weight and dressing percentage of the experimental broilers were not significant. The highest dressing weight of the experimental broilers in the various treatment groups was 1.70 kg/bird (T_1), followed by T_2, T_3, T_4, and T_5. However, the highest dressing percentage (78.71%) was obtained in T_2, followed by T_1 (77.63%), T3 (73.84%), and T_4 (71.27%), and the lowest (70.48%) dressing percentage was detected in the positive control group (T_5). Rehman et al. [45] concluded that apart from dressing percentage, no interaction or individual effect of probiotics and prebiotics was observed for carcass, breast, thigh, heart, liver, or gizzard weight. The effects of prebiotics, prebiotics, and synbiotics on the breast meat weights of broilers were significantly different between the treatment and control groups. The results revealed that the thigh meat weight of the carcass did not differ significantly after broiler chickens were supplemented with prebiotics, prebiotics, or synbiotics. The effects of prebiotics, prebiotics, and synbiotics on broilers' heart and gizzard weights were not significantly different between the treatment and control groups. The highest heart and gizzard weights were observed in T_1 and T_2, respectively. Conversely, the lowest heart and gizzard weights were observed at T_5. The liver weights of the broilers in the treatment and control groups were significantly different. The highest liver weight was observed in T_2 (49.00 g), followed by T_1, T_3, and T_4. On the other hand, the lowest liver weight was observed in T_5 (37.33 g). A pH of 6.0–6.8 is preferred for broiler production, but birds can tolerate a pH range of 4–8. A pH greater than 8 could cause reduced water intake [27]. The inclusion of prebiotics, probiotics, or synbiotics in drinking water decreased the pH of the drinking water, whereas the inclusion of antibiotics increased the pH. The pH in particular regions of the GIT is a factor that establishes a particular microbial community and influences the digestibility and absorptive value of most nutrients. Most diseases causing-microorganisms grow best at a pH of 7 or slightly higher. Beneficial microbes, on the other hand, coexist with diseases in an acidic pH range (5.8–6.2). Probiotics modify the intestinal ecosystem by supplying digestion enzymes, reducing pH, and increasing enzyme activity in the gastrointestinal tract [46]. Probiotics greatly affect the intestinal microbiota and work against Salmonella to prevent infection in birds, which have beneficial effects on performance [47]. Prebiotics are necessary for better survival of probiotics in the gut. Probiotics can dwell well in the digestive system with the help of prebiotics because they can tolerate an anaerobic environment, e.g., low oxygen, low pH, and low temperature. Prebiotics serve as substrates for probiotic survival and growth in the lower gut, where they participate in symbiotic relationships [27]. In addition, lowering the pH of organic acids improves nutrient absorption [48]. The effects of heat stress on feed and water intake were substantial. The experimental birds consumed 5 times more water than their feed when the environmental temperature was above 38 °C. The differences in the percentages of surviving broiler birds supplemented with prebiotics, probiotics, or synbiotics were significant. The best survivability percentage was detected in T_1 (100%), and the lowest survivability was detected in T_4 (66.6%). Studies have indicated that feeding prebiotics improves growth performance, reduce mortality and morbidity, or increases disease resistance [15–17]. On large-scale production, performance improvements in numbers may be economically significant. Prebiotics also increased body weight by 5.41%, lowered FCR by 2.54%, and decreased mortality by 10.5%, according to Hooge and Connolly [49].

Prebiotics have two main probable modes of action. First, they pass through the upper gastrointestinal tracts of the chicken without being digested by the host animal. They can then serve as substrates for bacteria such as Bifidobacteria and Lactic acid. Additionally, prebiotics leads to increased gut activities, including the production of Lactic acids and short-chain fatty acids as byproducts of microbial fermentation. These actions help slow down the rate of pathogen colonization in the poultry gut and boost the immune system (Fig. 5) [50].

In Bangladesh, fruits such as bananas, papayas, and watermelons are widely grown and consumed. These crops have significant economic and social significance, but their byproducts are typically thrown away. Incorporating fermented banana peel into the diet reduces the number of coliforms in the ileum. As a result, such fermented byproducts are suitable as feed supplements in broiler rations [54].

Conclusion

In conclusion, prebiotic supplementation significantly contributes to production performance and survivability. Similarly, the highest carcass yield and giblet yield weights were observed in the prebiotic group. Therefore, to improve production performance and increase the survival of antibiotic-free broilers in hot climate regions or heat stress conditions, the proposed prebiotics could

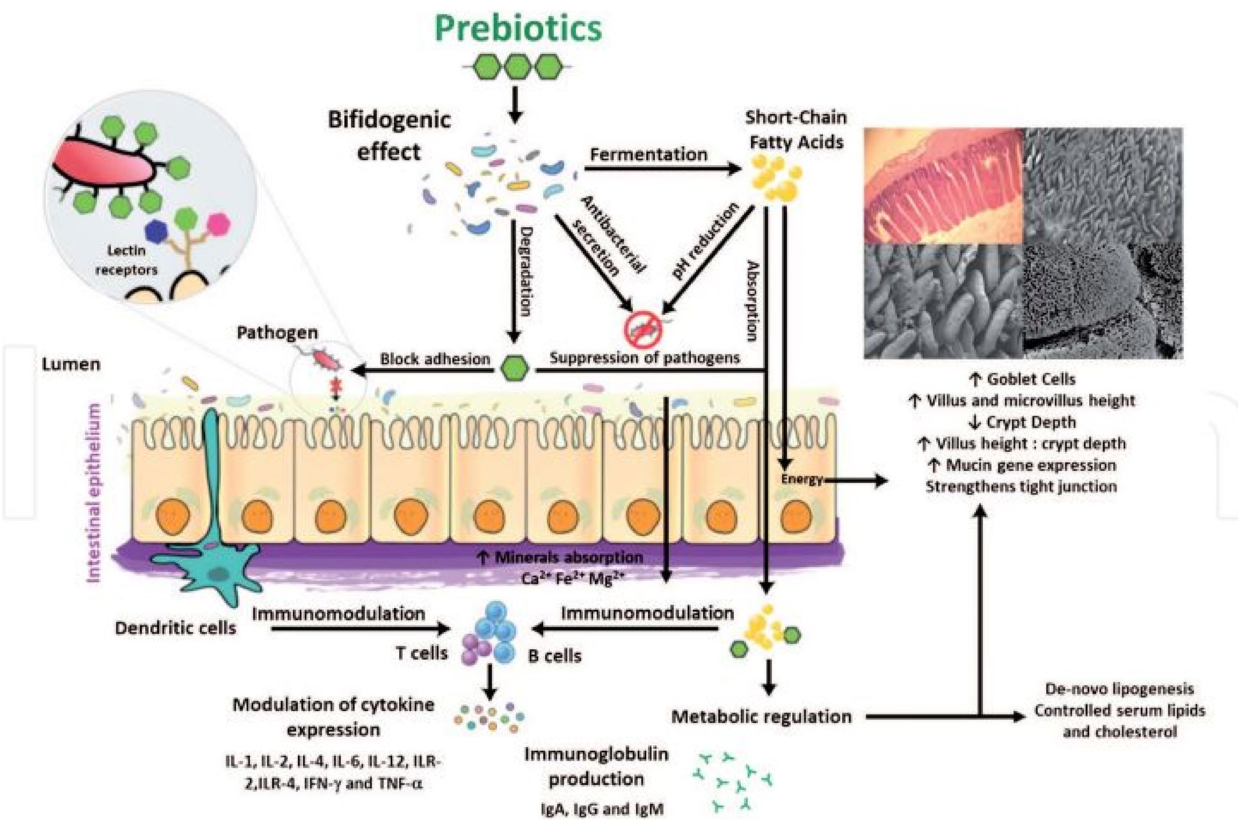

Fig. 5 Mechanisms of action of prebiotics in poultry species, showing positive effects on immunity, gut health, metabolic activity, and pathogen colonization (Permission from [51], [52], [53])

be used effectively and economically. However, immune responses, blood biochemical parameters, gut microflora, and antimicrobial resistance of the experimental birds were not performed, and hopefully, we will investigate these parameters in our near future projects.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

MSI conceptualized the theme of the manuscript and the design of the experiment. MZI, JR, MSA, MLT, and MAH performed most of the experiments in the manuscript. MZI performed the preliminary experiments described in the manuscript. MAH, AHH, and MMH prepared the herbal extracts and Figs. 1–4 of the manuscript. MSI and MZI performed the statistical analysis. SSJ and AK edited and reviewed the manuscript. The manuscript is reviewed, revised, and approved by all authors for publication.

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Data availability

No datasets were generated or analysed during the current study.

Availability of data and materials

The datasets used in this manuscript are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

All procedures associated with the animal model were carried out in compliance with the Institutional Animal, Medical Ethics, Biosafety, and Biosecurity Committee of the Institute of Biological Science (IBSc) of the University of Rajshahi, Bangladesh (protocol id: 248/359/IAMEBBC/IBSc).

Consent for publication

All authors reviewed, revised, and approved the final draft for publication.

Competing interests

The authors declare no competing interests.

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